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THE GRAPE LEAF-HOPPER.

By H. J. QUAYLE.

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OUTLINE.

PAGE.

GENERAL CONSIDERATIONS 177
Early accounts; Destructiveness; Distribution, general, local.

LIFE HISTORY AND HABITS 181
OVERWINTERING ADULTS 181
Food habits; Relation of food to development and activity; Influence of temperature upon activity; Proportion of the sexes; Migrations; Time they attack the vine; Do they feed exclusively on the vine; Habits on the vine; Copulation and oviposition.

THE EGG 186
Description and appearance; Where laid; Number; Rate of egg laying; Incubation period; Percentage of eggs that hatch; Effect of oviposition upon the leaf.

THE NYMPH 192
The hatching process; First stage; Second stage; Third stage; Fourth stage; Fifth stage; Moulting; Habits of feeding; Transfer to other food plants.

THE ADULT 196
Time of reaching maturity; Feeding habits; Copulation and oviposition; Activity and migrations; Activity of the sexes; Proportion of the sexes; Differences in coloring; The varieties of the species *comes*; Proportion of the varieties; Common name of the insect; Preferences for different varieties of vines.

DEVELOPMENT 200
Length of life cycles; Number of generations; Comparisons of development in other localities.

NATURAL CONTROL 202
Climatic; Parasitic; Predatory; Fungous.

MECHANICAL CONTROL 203
Blowers and suction; Torches; Dry powders; Sticky shields; Fumigation; Sprays and washes; Screens or cages.

FARM PRACTICES 214
Plowing; Sheeping.

SUMMARY 215

LITERATURE 217

THE GRAPE LEAF-HOPPER.

(*Typhlocyba comes* Say.)

By H. J. QUAYLE.

GENERAL CONSIDERATIONS.

Early Accounts.—The grape leaf-hopper was first named and described by Thomas Say[1] in the year 1825. Specimens were taken

Fig. 1. Grape leaf showing first indication of injury due to hoppers. The white specks represent where the insects have been feeding.

that year from Missouri, and three or four years later it was reported as an important pest of the vine in Massachusetts. Harris[2] in 1841 wrote the first complete account of the insect and fully appreciated

[1] Jour. Acad. of Nat. Sciences, Phil. iv. 327.
[2] Harris, Ins. Inj. to Vegetation, Flint Ed., 227.

the injury caused by it, and ever since that time it has occupied a very important place in the literature of grape insects in this country. Harris's account of the insect remained the standard for a long while, and no very thorough work was done on the life history of the insect until it was undertaken by Slingerland in 1901.[1]

In California it has been reported as a pest of the vine since 1875. The accounts of insects in the "Pacific Rural Press" furnish a fairly good index on the occurrence of injurious species in this State, and the first account there given is in the issue of April 12, 1879. Notices regarding this insect have appeared frequently in

Fig. 2. Young grape leaves in advanced stage of hopper injury. These leaves had completely dried up and fallen to the ground in the early spring. Photographed April 20, 1907.

the press of the State, as well as other publications, since that time. Brief notices of its occurrence have been printed in the State Horticultural Commission reports, and a bulletin on the insect was issued from this station in 1897.[2]

Destructiveness.—With the exception of the phylloxera, the vine hopper is undoubtedly the most destructive insect pest of the vine in the State. It is more uniformly present than any other insect

[1] Slingerland, Cornell Exp. Sta. Bull. 215.
[2] Woodworth, Cal. Agr. Exp. Sta. Bull. 116.

attacking the vine, and each year in some parts of the State it occurs in very great numbers, and, in such sections, it levies a heavy tax upon the vineyard interests. To give expression to this loss in money value, for example, in one vineyard of about a thousand acres near Madera, the owner estimated that the damage done last year by hoppers would aggregate about $10,000.

The grape leaf-hopper belongs to the class of injurious insects that obtain their food by sucking the juices from the plant. Scale insects and plant lice are other well known pests belonging to this same general group, which obtain their food in much the same way that the mosquito sucks our blood. The sharp pointed beak or proboscis of the hopper (Fig. 4) is thrust into the tissues of the grape leaf and the liquid parts extracted therefrom. The feeding is done mostly on the underside of the leaf, and those leaves around the base of the vine are the ones first attacked.

Fig. 3. The foliage and fruit of the grape is often badly smutted by the excrement of hoppers. The black specks on the above leaf indicate this.

The first indication of their work is a mottled appearance of the leaf due to the pale spots formed wherever the beak has been inserted and the green parts taken out (Fig. 1). As the feeding continues these spots become more numerous, and this pale yellow color spreads over the entire surface; and finally the leaf turns brown and drops off (Fig. 2). This injury has been observed as early as April or May, and thus the vine from the very beginning of the season is prevented from making its normal growth. As the hoppers increase in numbers the injury increases with the advancement of the season. In midsummer quite a large area about the crown of the vine will show all the leaves pale colored or completely dried up, and, in severe cases, the entire vine is thus affected. This drying up and dropping off of the leaves allows the sun to have free access to the fruit and may cause sunburn. We have seen the fruit thus exposed and badly sunburned as early as the middle of June. The falling off of the leaves prematurely also pre-

vents the berry from maturing properly since it is in the leaves of the plant that the sugar of the berry is manufactured. The grape thus loses much of its flavor and sweetness, and likewise the characteristic coloring, which is so desirable in certain table varieties, is not attained. The fruit, furthermore, is badly smutted by the exudations of the insects, and this serves as a harboring place for the collection of dust and dirt, and for the growth of fungi (Fig. 3). The dropping of the leaves or any interference with their normal functions likewise has its effect on the growth of the wood of the vine. The canes fail to ripen normally for the next year's wood, and many of the buds fail to develop in the following spring. The vine may thus be more or less permanently stunted in growth, and even killed in severe cases of grape leaf-hopper injury.

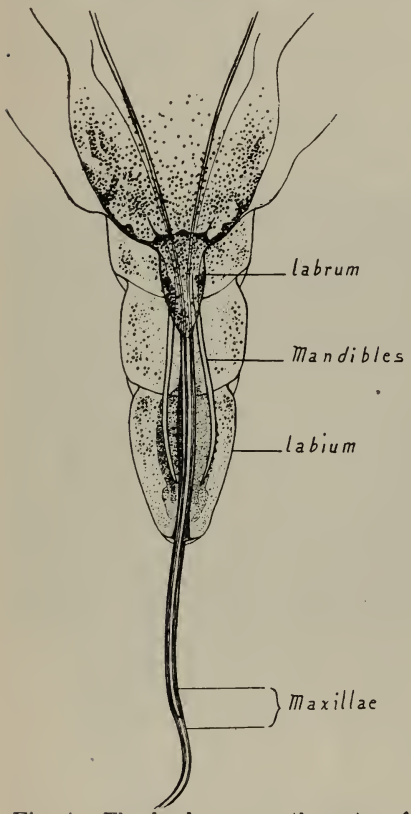

Fig. 4. The beak, or mouth-parts, of the grape leaf-hopper. Much enlarged.

Distribution; General.—The grape leaf-hopper (*Typhlocyba comes* Say) is a widely distributed native American insect occurring in the United States practically wherever the vine is grown. It is frequently notably injurious in the grape belts of New York and Ohio, as well as other less important grape sections in this country. In Europe this species is replaced by two other related species, *Typhlocyba flavescens* and *Typhlocyba viticola*. The former seems to be the more injurious of the two and occurs throughout all of temperate Europe and northern Africa, while the latter is confined mostly to Italy and the neighboring islands.[1]

Local.—In California our species is found in practically all of the vine growing sections, but is most injurious in the Sacramento and San Joaquin valleys. In the coast valleys another larger species (*Tettegonia atropunctata*) is frequently injurious, most commonly during the earlier part of the season. This species appears not to feed exclusively on the vine, and during midsummer and later is

[1] Mayet's Insectes de la Vigne, 168.

distributed over other food plants. During 1907 the grape leaf-hopper was particularly abundant in many of the vineyards about Fresno, and also in the lower part of the San Joaquin Valley around Lodi.

LIFE HISTORY AND HABITS.

OVERWINTERING ADULTS.

During the colder weather of winter the hoppers may be found in large numbers in the leaves or rubbish in the vineyard, or along the bordering roadsides and fences. Where leaves have been blown together in bunches or lodged in weeds or grass over the vineyard or its borders, hoppers will be especially likely to be present during the colder or wet rainy days of the winter season. They will also be found harboring low down along the fences or in the weeds or other growth among the vines. Alfilaria, one of the commonest plants in many California vineyards in winter, forms a close rosette on the ground, and hoppers will be found abundantly under the low spreading foliage of this plant.

Food Habits.—The grape leaf-hopper feeds on a large variety of plants during the winter season. It will be found feeding chiefly during the warmer days of winter, and resting more or less dormant during the colder or rainy weather. It attacks practically everything that may be growing in the vineyard or vicinity, although a preference is shown for certain plants. Alfilaria is readily attacked by these insects, and where hoppers are numerous the foliage of this plant will be seen to have a pale yellow color as a result of their work. The low spreading foliage seems to offer suitable conditions for the hoppers when they are not feeding, so that they will be found on the underside of these plants almost continuously, regardless of the kind of weather. Burr clover is also readily attacked by the hoppers in winter, as well as rag weed, dock, wild mustard, alfalfa, and several kinds of grains and grasses. They show a preference, however, for such plants as the alfilaria and the clovers as against the grains and grasses.

The hoppers that were taken into the laboratory in the early spring invariably died in the course of two or three days if deprived of food. Under the same conditions they were easily maintained upon alfilaria or other food. They were confined in lantern globes which were placed in the open window of the laboratory, so that the conditions as regards temperature and moisture were not very different from that of the vineyard. Hoppers were also confined in lantern globes in the vineyard, but in all cases they died very soon without food, though the more dormant they were the longer they were able to survive.

Many of the hoppers succumbed to long continued wet weather or other unusual conditions in winter. After about two weeks of almost continuous rain we have counted as many as 700 dead hoppers under a single bunch of alfilaria. This mortality may be partly accounted for because of unsuitable conditions for obtaining food, though the direct effect of exposure to such conditions is probably the more important factor.

Relation of Food to Development and Activity.—The activity of the insects is dependent primarily upon food and temperature, and the latter largely influences the former. No matter how much nutritious food may be available, if the temperature is sufficiently low they become dormant and are revived only upon the rise of temperature; but once they become active through the influence of a higher temperature, they require food to maintain their activity.

Influence of Temperature upon Activity.—On the warm days of winter the hoppers are very active and fly up in large numbers before a person as he walks through the vineyard. On the contrary, on a cold or wet day they may only be disturbed by actually moving the object upon which they are resting, and then they will fly but a very short distance,—not more than a foot or two generally. It is possible during such days to pick up the leaves, with a dozen or more hoppers resting on the under surface, and place them in a cyanide bottle without disturbing them. They are most active during the warmer portions of the day,—from nine or ten o'clock in the morning, when the dew is dried from the leaves, until three or four in the afternoon.

Experiments carried on in the laboratory to determine the effect of temperature on overwintering adults indicated that a temperature of 110° F. was nearly always fatal. These experiments consisted in confining the hoppers in a double glass vial and heating gradually with artificial heat. A small homo vial was contained within a larger one, and a thermometer extended through the corks of both vials so that the bulb was contained in the center of the inner vial with the hoppers. Cotton was placed in the bottom of this vial to prevent them from coming in contact with the glass when they would fall down. The whole apparatus prevented so far as possible the unequal heating of the sides of the vial as compared with the air in the interior.

In some of the experiments, as given in the table below, the temperature was first reduced by ice and salt to 30°F. or lower, and suddenly raised again to a point at which all the insects were killed. By consulting the table it will be seen that they became dormant at 60° to 65°F. and revived again at about 70°F. At 80° to 90°F. the first

of them would be killed by the heat. The optimum temperature under these conditions was between 70° and 85°F. The temperature of the room during the experiments was between 65° and 75°F. In most of the experiments it was the ordinary air of the room, as regards humidity, but in some a moist plug of cotton was contained in the vial with the insects, and thus the humidity was considerably increased.

The experiments in detail are tabulated below:

Temperature Experiments.

Date.	Experiments.	Insects, Number	Room Temperature	Inactive at	Fell to Bottom Vial at	Temperature Reduced to	Active at	First Dead at	Last Dead at	Time of Experiment
			°	°	°	°	°	°	°	
1907—March 20	1	7	66					85	110	3m
March 20	2	8	66					90	110	4
March 20	3	8	70					95	110	10
March 20	4	8	72					95	110	6
March 20	5	8	72					100	110	5
March 20	6	8	72					110*	120	5
March 20	7	8	72					105*	115	6
March 20	8	8	72					100*	110	8
March 23	9	8	70	50	50-40	30	70	100	110	15
March 23	10	7	68	60	50-45	45	70	105	110	12
March 23	11	6	70	65	60-50	35	76	87	102	10
March 23	12	6	70	65-60	62-55	25	74-8	86	94	13
March 23	13	6	70	66	64-56	30	64-72	84	110	11
March 23	14	6	70	60	60-54	40	57-66	80	114	15
March 23	15	10	70	62		28†	65-72	84	102	20
March 23	16	6	72					105	120	
March 23	17	7	72					100	110	
March 23	18	8	72					105	110	

*Vial kept moist by wet plug cotton. †Held for 10 m.

In the column "Inactive at" is indicated when the hoppers ceased moving about, and in the column "Active at" when they first regained their locomotive powers. The general conclusions suggested by these experiments are as follows:

A rise in temperature to 110°F., and in one or two cases to 120°F., invariably killed the hoppers. With moisture in the tube they appeared to withstand a slightly higher temperature. Cold to as low as 25°F. had no effect upon them except to make them temporarily dormant. When they were subjected again to the higher temperature they were killed the same as if started from the room temperature, except, apparently, to make the first succumb at a lower temperature. The practical bearing of these experiments can hardly be interpreted beyond the fact that a sudden rise in temperature may be fatal to some of the insects. In this the rather unnatural condition of dry, artificial heat must also be taken into consideration.

Proportion of the Sexes of Overwintering Hoppers.

Collected.	Number of Specimens Examined.	Females.	Males.	Percentage Females.	Percentage Males.
March 6th	1,500	675	825	45	55
March 28th	130	65	65	50	50
April 12th	272	175	97	64.4	35.6
April 19th	127	72	55	57	43
April 29th	134	100	34	74.6	25.4
Totals and av. percentage	2,163	1,087	1,076	50.26	49.74

It will be seen from the average percentage in the above table that there is practically no difference between the numbers of the sexes, so that we may conclude that both sexes are able to withstand the winter conditions equally well.

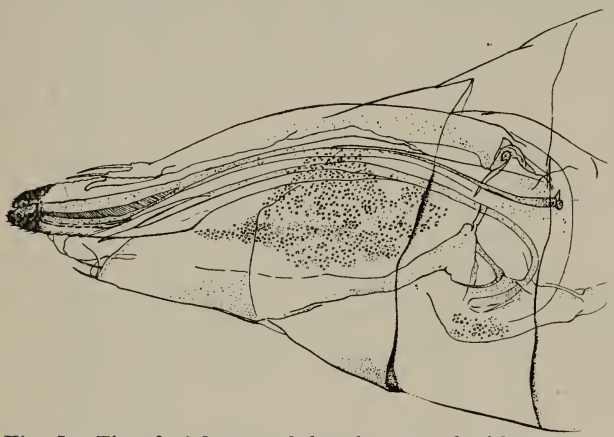

Fig. 5. Tip of abdomen of female grape leaf-hopper, showing ovipositor. The black tipped appendages, the cerci, obscure the other parts of the ovipositor shown in Fig. 6 below. Greatly enlarged.

Migrations.—When plowing is begun in the vineyard in the spring, before the foliage appears on the vine, the food supply—consisting of whatever vegetation may be growing—is turned under and most of the hoppers are obliged to look elsewhere for food. Some of the insects remain in the vineyard and subsist upon what little growth may be left by the plow. The larger number, however, must look elsewhere for food, and this is generally found in the immediate vicinity, usually around the borders of the vineyard. We have seen all the vegetation growing along the roadsides of badly infested vineyards completely deprived of the green coloring matter. After the vineyard was plowed the hoppers continued to feed here, largely, until the vines came into leaf, when they migrated back into the vineyards. These are the only distinct movements we have observed with the overwintering hoppers in the spring.

Time they Attack the Vine.—The first observed feeding on the grape foliage at Lodi during 1907 was March 28th, on an old Mission vineyard that was considerably in advance of the other surrounding vineyards. A week or two later, however, the foliage in many vineyards was far enough along to attract a good many of the hoppers from their

varied winter food plants. In 1908 an occasional hopper was found on vines in the Sonoma Valley as early as March 18th.

Do they Feed Exclusively on the Vine?—Once they begin to feed upon the vine they do not leave it for other food unless, of course, they incidentally happen to find themselves in other situations. During two or three weeks while the vine is coming into foliage, some hoppers may be found on the vine and others on the winter food plants, but those that are still feeding on the other vegetation have not yet found their way to the vines. It may be a couple of weeks after the first foliage appears, therefore, before all the hoppers will be found on the vine; but, once they begin to feed on the grape, they remain until the vine becomes dormant at the end of the season.

Fig. 6. The two pairs of valves of the ovipositor with which the insect inserts its egg into the leaf tissues. Greatly enlarged.

Habits on the Vine.—While the leaves are still expanding and not yet affording much protection the hoppers will be found most commonly on the concave side of the leaves that are not yet fully expanded, or on the leaves near the base of the vine, where they are not so completely exposed. At this period they were not observed to move about to any extent, and seemed to be pretty well occupied with feeding.

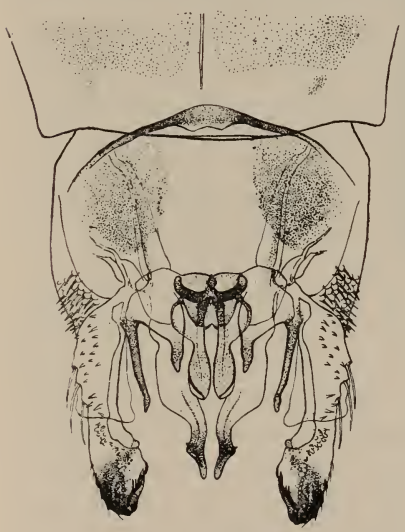

Fig. 7. Tip of abdomen of male grape leaf-hopper. Much enlarged.

Copulation and Oviposition. — On April 30, 1907, they were observed pairing for the first time. This was approximately three weeks after they had begun to feed upon the vines.

The first eggs were seen in the leaves on May 4th, and from this date on the hoppers were laying eggs almost continuously. Egg laying occurs then just about one month after feeding begins on the vine. The eggs are remarkably well tucked away in the leaf tissues by means of a sharp lance-like ovipositor, as shown in figures 5 and 6.

THE EGG.

Description and Appearance.—The eggs of the grape leaf-hopper are very minute objects about three hundredths of an inch long and about one third as wide. They are slightly bean-shaped, as shown in figures 8 and 9. As they are situated naturally in the leaf, within the tissues, they are difficult to detect unless one is familiar with their appearance. If the light is at the right angle the epidermis will be seen to be raised and slightly more transparent than the surrounding tissue, and the form of the egg distinguished beneath. We occasionally met growers who claimed to have observed the eggs on the underside of the leaf; but they were mistaken in thinking that little transparent droplets of sap were the eggs of the hopper. These are exudations of sap which usually occur along the larger veins, and do resemble somewhat an insect egg. The outer surface of these droplets of sap soon hardens or becomes viscid on exposure to the air, thus resembling the shell of an egg and making the similarity more complete.

Fig. 8. The egg of the grape leaf-hopper photographed in its natural position within the tissues of the leaf. The circular spot at the top represents the eye of the developing nymph within. Greatly enlarged.

Where Laid. — Harris,[1] in 1841, stated that the eggs of the hopper were laid on the leaves, but this statement appears not to have been substantiated by actual observation. Townsend[2] in 1891 supposed that the drops of sap, mentioned above, represented the egg punctures of these insects, but this is now known to be erroneous. Marlatt[3] in 1895 stated that "the eggs are thrust by the female singly into the substance of the leaf on the lower side, either into the midribs and large veins or in the intervening spaces." Photographs were taken of the eggs in the leaf in 1898 by Professor Woodworth of this station, and these are still on file here. The first complete

[1] Insects Injurious to Vegetation, Flint Ed., p. 228.
[2] Bulletin No. 3, N. M. Agr. Exp. Sta.
[3] U. S. D. A. Yearbook, 1895, p. 402.

account of the egg and the first published pictures were given by Slingerland[1] in 1901.

It is now very well known that the eggs of this insect are laid just beneath the epidermis on the underside of the grape leaf. This is by far the most usual position, though they were occasionally found on the upper surface. They are generally distributed over the leaf surface, and occupy no special position in relation to the veins or ribs of the leaf. Some will be found in the tissue of the rib itself, a good many along the side of the ribs, and others scattered about over the general surface. They will be found also around the very edge of the leaf. In thousands of eggs seen during the summer we failed to find any arranged in rows as was found by Slingerland in New York.[2] The six or seven eggs laid in a row parallel with one another would represent a single laying of a hopper, and there is no reason why this should not be done occasionally, but it is not the usual occurrence here. We have found them with two or sometimes three arranged more or less parallel, but never more than this number. In our individual breeding cages, where we obtained several hundred eggs, and where the space was limited, they were promiscuously scattered about, one in a place.

Fig. 9. The egg dissected from the leaf and photographed on a microscope slide. Particles of leaf tissue are shown still adhering to the egg. Greatly enlarged.

We confined several hoppers, taken in pairs, and liberated these in cages on currant, blackberry, loganberry and almond, peach, cherry, and a few other plants, but did not succeed in obtaining eggs from these food plants. In most cases the insects were found dead when the cages were examined three or four weeks later. We selected the particular plants named because they were convenient, and not because the eggs would be more likely to be laid on these than on other plants. Possibly more nearly related plants, botanically, would be found suitable for oviposition. The Virginia creeper is said to be readily attacked by this insect,[3] and we presume eggs are laid on this plant. Since, however, this species is a grape pest exclusively, that is, during the growing season, and all the experience indicates that it feeds only upon the grapevine, it may be stated, so far as the economics of the insect is concerned, that the eggs are laid only in the leaves of the grape.

[1] Cornell Agr. Exp. Sta. Bull. 215.
[2] Slingerland, Bull. 215, Cornell Exp. Sta.
[3] Gillette, Colo. Sta. Rept. 1900.

Number.—The number of eggs which are laid by this insect, so far as we have been able to find, has not been previously recorded. It has been stated approximately as one hundred, and this, so far as our experiments went this year, is not very far from correct. We were able to make individual records of a number of hoppers, and found that the

Fig. 10. Experimental vine used in the laboratory for obtaining data on the life-history of the hopper. Cages used for confining the insects are shown on the leaves.

number laid varied from forty to one hundred and twenty-one. These were under laboratory conditions, but not very different from that of the vineyard. The hoppers were confined in cages attached to the growing leaves, as indicated in figure 10.

These cages were made by cutting a square or rectangular opening in a piece of cardboard, on the underside of which velvet was glued with pile side outward. This rested on the surface of the leaf and on

the opposite side; for the purpose of holding the leaf firmly against the cage, a piece of transparent gelatine was used, it being cut to correspond with the pasteboard on the opposite surface. These were held together on the leaf by means of ordinary paper clips. Strips of fairly thick paper were glued on the upper side of the pasteboard, leaving one edge free, under which an ordinary cover glass could be pushed. These cover glasses could be readily changed and kept clean, and the specimens could be easily examined, if necessary, with a compound miscroscope. Only forty eggs were laid by two or three hoppers, but these probably died prematurely. This number was laid in about two weeks, which is a shorter period than most hoppers evidently live. One laid ninety-six, two one hundred and ten, and one one hundred and twenty-one. Since our observations in the field indicate that most of the hoppers continue to lay eggs for one to two months, the number of eggs laid will probably average from seventy-five to one hundred and twenty-five.

Rate of Egg Laying.—In the case of three or four hoppers we were able to follow pretty closely the rate at which the eggs were deposited, and the total length of the oviposition period. The following tabulation for one of these is given below. The totals are carried out for each date:

Rate of Oviposition.

Copulated June 23d. Cage 51.

Date.	Number of Eggs Laid.	Date of Appearance of Nymphs.	Hatched Number.
June 30	13	July 10	13
July 2	14	July 17	40
July 3	19	July 18	43
July 6	35	July 19	49
July 7	35	July 20	52
July 9	45	July 22	53
July 16	57	July 23	58
July 17	63	July 24	60
July 19	68	July 26	62
July 22	75	July 27	63*
July 23	75		
July 24	79		
July 25	79		
July 26	79		
July 27	79		
July 31	85		
August 1	85		
August 2	85		
August 4	91		
August 7	105		
August 9	107		
August 12	111		
August 16	121		
August 17, hopper dead.			

*Total laid to July 17th. No further hatching record was kept for short intervals.

Incubation Period.—A large number of hoppers were liberated on our experimental vines at 9 A. M. May 29th, and removed at noon

on May 30th. About twenty eggs were laid on the vines within this period and the time for hatching noted. About half of these eggs were enclosed in individual cages and an accurate record kept on the whole number. The first nymph hatched on June 17th and the last June 20th, thus requiring a period of from seventeen to twenty days for the hatching period.

The above records were made on eggs laid by the hoppers which had remained over winter and on the dates given. There was a great difference however in the time required for hatching of the eggs from the spring brood. The observations were made during July and August and included records on two or three hundred eggs. The period required for hatching here was from eight to twelve days, all of the two or three hundred eggs coming within this limit. We can account for the difference only in the higher temperature of the later months or in the character of the eggs from the two broods. There was not much difference between the temperature in June and July in the Lodi section, hardly enough to account for all the difference in embryonic development. It may be possible that the vigor of the adults and the increased development of the egg when laid will account for this difference over the spring brood.

The time required for the eggs to mature in the ovaries was determined as from five to seven days. A number of pairs in coitu were liberated in the cages and the first eggs laid in five to seven days later.

Percentage of Eggs that Hatch.—The table indicating rate of oviposition on page above shows that of the first sixty-three eggs laid every one hatched. The hatching was less accurately kept for the remainder, but we are quite sure that every egg laid by this particular hopper brought forth a nymph. In the case of forty eggs laid by another hopper, all hatched. With the layings from most of the hoppers in our breeding cages a very high percentage of the eggs matured. This was not true of all, however. In one case a hopper laid a total of thirty-five eggs, scattered along over a period of three weeks, and only five out of the thirty-five hatched. In another case fourteen eggs were laid by an individual and none hatched. This experience in the laboratory of a very large percentage of mortality in some layings was also observed in the field. On one side of a particular vineyard where hoppers were exceedingly abundant in 1907, the worst infested field seen during the season, there was a very great mortality in the egg stage. On a single leaf taken from this particular area we have counted a total of seven hundred and forty-seven eggs that failed to mature. These could be very readily detected on the leaf by the dead epidermis covering them, which was dark brown to black in color. The leaf was thoroughly sprinkled with these black areas, and showed

fairly well in a photograph, but not distinct enough to reproduce here. Upon examining these eggs that failed to hatch they appeared not to have started their course of development, or in other words, were infertile. The egg itself was generally found to be fresh and intact, the black color on the leaf being due in most cases entirely to the epidermis over the egg. This was in a vineyard where the hoppers appeared in innumerable numbers in the early spring, and the eggs laid were from hoppers that had remained over winter. The mortality in the egg stage reduced their numbers to a very appreciable extent. What was true of this one vineyard in 1907 was observed very generally in the vineyards around Lodi in 1908.

We tried to account for this failure of the eggs to mature from a number of causes, but the matter is still unsatisfactorily settled. We first started on the supposition that something in the nature or make-up of the leaf, or a bacterial or fungous disease of the egg, might be responsible. The underside of the leaves of these vines were covered over more or less with pubescence or hairs. That this might have some effect in a mechanical way by holding moisture and thus furnishing the best conditions for producing disease was not borne out, since the same conditions were noted elsewhere with practically no mortality. The hoppers themselves seemed to be as healthy as those elsewhere, and a miscroscopical examination showed nothing unusual. That the eggs were infertile seems evident, but the exact cause in this particular area is not yet accounted for. Males were present in their normal numbers, and our experiments thus far indicate that they do not reproduce parthenogetically.

The exact causes of such conditions as these will largely account for the sudden disappearance of the hoppers after having become very abundant. It is well known that hoppers, like many other insects, have their ups and downs as regards numbers. In 1897 the hoppers were so abundant about Fresno during the winter that the people appealed to the University for aid in combating them for the approaching season. An investigation was undertaken by Professor Woodworth and headquarters opened for a season's campaign; the hoppers appeared in great numbers in the spring, as was to be expected from their abundance in winter, but the majority failed to lay eggs and none appeared to be normally productive, and as a result there were scarcely enough of the new generation produced to furnish good material for the investigation. From what is known of the history of the pest in the State, this is an example of what occurs more or less periodically.

Effect of Oviposition on the Leaf.—So far as we could see the puncturing of the leaf tissues for egg laying had no appreciable effect on the functions of the leaf. In many cases it was hard to tell where

an egg had been after hatching. In others the epidermis was blackened. In the case of the mortality in the eggs, already referred to, these spots were very numerous and probably interfered somewhat with the normal functions of the leaf, but ordinarily these small punctures have no noticeable effect on the leaf.

Fig. 11. The five nymphal stages of the grape leaf-hopper. All photographed to the same scale, thus showing the relative size of the different stages; also the development of the wing pads. Greatly enlarged.

THE NYMPH.

The young, immature hopper is called a nymph. It differs from the adult chiefly in the fact that the wings are not fully developed. These are gradually acquired with each of the five successive molts until after the last stage, when the adult with fully formed wings appears. The stages may be easily recognized by the development of the wing pads. The relative size is indicated in the photographs (Fig. 11), which were all taken under the same magnification.

The Hatching Process.— Several young nymphs were observed in the process of emerging from the egg covering, and it generally required from ten to fifteen minutes for this process. After remaining quiet for a few minutes just outside the eggshell they would move about until they found a suitable place for inserting their beaks for food, where they would remain

quiet for some time. For a few days before the eggs hatch there is a conspicuous dark spot at one end of the egg, which represents the eye of the developing nymph within. It is at this end that the egg covering is broken and the nymph makes its way out.

First Stage.—The young nymph upon hatching from the egg is a very small semi-transparent whitish creature with conspicuous red eyes. The wing pads are invisible. The head and thorax appear large in proportion to the abdomen, and the insect walks in a more or less wabbling manner. The length of the period from hatching to the first molt is four days.

Second Stage.—After the first molt the conspicuous red pigment in the eyes is partly lost, and the form of the body becomes more cylindrical. Indications of yellow markings appear on the thorax, and the wing pads just begin to appear as lateral buds. The length of this stage is two days.

Third Stage.—The markings of the thorax become a little more prominent, and the wing pads appear as buds extending posteriorly to the caudal margin of the first segment of the abdomen. The hind margin of the thorax is curved or arched, as a result of the wing pads projecting posteriorly at the sides. The length of this stage is three days.

Fourth Stage.—There is not much change in the general appearance, except that the wing pads are now conspicuously larger and extend to the caudal border of the second abdominal segment. The length of this stage is four days.

Fifth and Last Stage.—The wing pads now extend to the caudal border of the third, or to the middle of the fourth, abdominal segment. The length of this stage is five days.

After the fifth molt the fully formed wings appear, extending to beyond the tip of the abdomen.

Some of the life-history work carried on to determine the number and length of the nymphal stages is indicated in the following table:

Cage No.	Hatched between—	First Molt.	Second Molt.	Third Molt.	Fourth Molt.	Fifth Molt.	Adult Stage, Total.
52	9 P. M. July 17 to 9 A. M. July 18	7-22	7-24	7-26	7-30	8-4	17
53	4 P. M. July 17 to 9 A. M. July 18	7-22	7-23	7-26	7-30	8-4	17
54	9 P. M. July 17 to 8 A. M. July 18	7-22	7-24	7-26	7-30	8-4	17
55	4 P. M. July 17 to 9 A. M. July 18	7-22	7-24	7-26	8-1	8-6	19
56	4 P. M. July 17 to 9 A. M. July 18	7-23	7-25	7-29	8-2	8-6	19
57	4 P. M. July 17 to 9 A. M. July 18	7-23	7-25	7-29	8-2	8-6	19
60*a*	6 A. M. July 22 to 8 A. M. July 23	7-26	7-31	8-2	8-5	8-11	19
62	7 P. M. July 18 to 8 A. M. July 19	7-23	7 24	7-27	7-30	8-4	16
63	7 P. M. July 18 to 8 A. M. July 19	7-23	7-26	7-30	8-1	8-6	18

Cage No.	Hatched between—	First Molt.	Second Molt.	Third Molt.	Fourth Molt.	Fifth Molt.	Adult Stage. Total.
64	8 P. M. July 19 to 8 A. M. July 20	7–23	7–26	7–30	8–2	8–7	18
65	8 P. M. July 19 to 8 A. M. July 20	7–23	7–26	7–28	8–1	8–6	17
66	6 A. M. July 22 to 8 A. M. July 23	7–26	7–28	7–31	8–4	8–9	17
66*a*	6 A. M. July 22 to 8 A. M. July 23	7–27	7–31	8–1	8–4	8–10	18
67	8 P. M. July 19 to 8 A. M. July 20	7–23	7–26	7–28	8–1	8–6	17
68	6 P. M. July 19 to 8 A. M. July 20	7–23	7–26	7–28	8–1	8–6	17
70	6 P. M. July 25 to 8 A. M. July 26	7–30	8–1	8–4	8–7	8–13	18
71	6 P. M. July 25 to 8 A. M. July 26	7–30	8–1	8–4	8–3	8–13	18
69	12 M. July 23 to 8 A. M. July 24	7–28	7–30	8–2	8–5	8–11	18
72	3 P. M. July 26 to 8 A. M. July 27	7–31	8–2	8–5	8–8	8–13	17

From the above table it will be seen that the shortest time required to go through the five nymphal stages is sixteen days, and the longest period nineteen days, the average being about eighteen days.

Summarizing the duration of each of the stages as given above, it will be, disregarding fractional days, as follows:

Stage.	Wing Pads.	Duration of Stage.
First	Invisible	4 days
Second	As lateral buds	2 days
Third	Extending to caudal border first abdominal segment	3 days
Fourth	Extending to caudal border second abdominal segment	4 days
Fifth	Extending to caudal border third abdominal segment	5 days
	Total	18 days

The total length of the nymphal life of the grape leaf-hopper in New York, as worked out by Slingerland,[1] is from thirty to thirty-three days. This is a difference of about two weeks from that of the same species in California. Climatic conditions probably account for this difference, although so far as temperature is concerned, there is not much difference between the section about Lodi in June and July and that of New York in the same months.

Molting.—As a preliminary step to the actual shedding of the skin, the nymph becomes quiet for a short period, then the old skin splits on the thorax and the nymph with its new covering makes its way out. The actual working out from the old skin required about ten minutes, and in a very short time thereafter it is able to move about as usual. Immediately after emerging from the old skin the insect is white in color and fairly transparent. The tracheal system can be followed very readily, especially in the younger nymphal stages, after emerging from its old integument. During the process of emerging the old skin seems to be held on to the leaf by the claws of the feet, and these often remain for some time attached to the leaf. The last nymphal skin, however, is much more firmly attached than the earlier

[1]Cornell Exp. Sta. Bull. No. 215, p. 92.

cast skins, and later in the season these last skins will be about all that will be seen adhering to the leaf. The accompanying picture, Fig. 12 (and on the cover of this bulletin), photographed by Mr. W. B. Parker, shows one of these cast skins and the adult which emerged from it.

Habits of Feeding.—The young nymph upon hatching from the egg soon finds a suitable place on the leaf for inserting its beak, and begins to feed on the plant juices. The majority of them remain during the earlier nymphal stages on the same leaf from which they originally emerged, but later there is more or less migration to other leaves on the vine; but probably a large number remain throughout their nymphal life on the same leaf.

Fig. 12. Adult grape leaf-hopper just emerged.

Leaves which had contained large numbers of eggs, some of which were hatched and some not, were always seen to be well stocked with nymphs, while other leaves immediately adjoining were free from both eggs and nymphs. Leaves which had already lost most of their green coloring matter were seen to have nymphs in abundance, while fresh green leaves near by, offering a better food supply, were observed to be very free from hoppers. Of course, the nymphs can not leap or fly, and so can not make their way from one leaf to another on different shoots unless they happen to be touching, or else crawl down to the base of the shoot and up on the new one. Leaves on the same shoot were observed to have a great difference in the number of hoppers, always being most abundant on the older and paler colored leaves, where the most eggs were to be found.

Transfer to Other Food Plants.—In order to determine whether nymphs would mature if transferred to other food plants than the

grape, we confined large numbers of nymphs in all stages on apple, almond, currant, blackberry, and peach, and in each case practically all completed their development in due course. Some of these were left on their food plants long enough to pair and lay eggs, but we were unable to find any evidence of eggs having been deposited. In another place it has been stated that adult females which were known to be fertilized failed to lay eggs on these same plants. It may be inferred then that nymphs will mature on other food plants, but it is at least unusual, if ever, that eggs will be laid elsewhere than on the grape.

THE ADULT.

Time of Reaching Maturity.—The first adults from the spring brood at Lodi were observed on June 8, in 1907, and on June 12, 1908, this being about two months after they had begun to feed on the vine in the spring. By the last of June newly emerged adults were very common. At this time many were seen pairing, indicating that they were fully mature.

Feeding Habits.—The habits of feeding of the adults are not very different from those of the nymphs except that they move about more. They will be found in greatest numbers on the leaves around the base of the vine and feeding with the nymphs. All through the season the hoppers, in whatever stage they may be, will be most abundant in the interior of the vine. This is probably for protection, since the food supply is not as good as that on the outside of the vine, for the older and less succulent leaves are around the base of the vine. So far as the food is concerned it would appear that the new leaves near the tip of the growing shoot would better satisfy them, as is the case with plant lice and some other of the sucking insects.

Fig. 13. The adult grape leaf-hopper, enlarged about twelve diameters.

Copulation and Oviposition.—Adults of the spring brood were seen pairing during the last of June, and most commonly about the middle of July. An occasional pair was seen during the first week in August, but after this none were seen throughout the rest of the season.

Egg laying began with the spring brood during the last week in June in 1907 and the same time in 1908. The overwintering hoppers were also still depositing eggs, so that there appeared an overlapping of the two broods.

Activity and Migrations.—While there was more or less moving about among the hoppers in the same vineyard, no migrations from one vineyard to another were observed until about the middle of July. At

this time, and later, hoppers were seen in some cases flying about the farmhouses some little distance from any vines. They were seen at night, and when the weather was warm and calm. They appeared not to be going in any particular direction. Such migrations or activity were only very occasional, and so far as we could see the numbers in the vineyards were not changed. In the cases noted there was no particular reason for the migration on account of food. We believe that favorable weather conditions caused greater activity on the part of the insects, and that they are just as likely to go back into the same vineyard as to make a distinct migration in a definite direction for change of food or other reasons.

Activity of the Sexes.—Both males and females seemed to be equally active as seen from the proportion of the sexes taken in the air with a net when disturbed, and the fact that they were found in all situations in about equal numbers would seem to indicate that there is no difference as regards the activity of the sexes.

Proportion of the Sexes.

Date	Number Examined.	Males.	Females.	Per cent Males.	Per cent Females.
May 20	200	59	141	29.5	70.5
May 20	200	75	125	37.5	62.5
May 22	100	65	35	65.	35.
May 22	308	150	158	48.7	51.3
May 22	167	89	78	53.2	46.8
June 8	140	75	65	53.5	46.5
June 8	215	85	130	39.5	60.5
Totals	1,330	598	732	45	55

Differences in Coloring Due to Age.—The hoppers in winter are distinctly redder in color, *i. e.*, the markings are more pronounced than at any other season. The reddish color becomes more conspicuous as the winter season approaches, after they have left the vine and began to feed upon their winter food plants. In the spring after they have been feeding for a few weeks on the vine they become distinctly paler in color again. This less conspicuous marking is then maintained throughout the life of the insect surviving the winter. While they have become distinctly paler in color after feeding for two or three weeks on the vine in the spring, they are not so pale colored as the newly hatched hoppers, and the individuals of the two broods may be distinguished for a time after their emergence. The hoppers of the second brood that are on the vines in the fall take on the more conspicuous coloring with the approach of the winter season, and this more pronounced marking remains until after they have fed for a few weeks on the vine in the following spring.

The Varieties of the Species Comes.—Altogether there are nine varieties of this species recognized in the United States.[1] All the specimens taken on the grape this year about Lodi and Fresno, California, were the typical *comes,* and the variety *coloradensis.* The difference between these two varieties is that *coloradensis* has a black spot on either side of the scutellum at the base, while in *comes* these

Fig. 13. A vine enclosed by a cheese-cloth cage, open at the top, for studying migrations.

spots are wanting. *Comes* largely predominates, as is indicated by the following table. The specimens were mounted on velvet between two miscroscope slides, and collected on the dates given:

Proportion of the Varieties of the Grape Leaf-hopper.

Date.	Slide.	Number.	Comes.	Coloradensis.
I—29	1	150	134	16
	2	155	135	20
II—17	3	145	129	16
II—15	4	155	142	13
January—June	5	136	122	14
V—25	6	96	80	16
Total		837	742	95
Percentage			88.64	11.35

[1] Gillette, Proc. U. S. N. M., vol. 20, 1898, p. 709.

Gillette, in the publication cited, states that *coloradensis* is a very distinctly marked variety and one that seems to be confined entirely to the West. This does not mean that it is limited to the Pacific coast states, for it occurs commonly in Colorado, and it is also found in Nebraska, Kansas, and New Mexico. Specimens of the California varieties were sent to Professor Gillette and he replied that they were the typical *comes* and *coloradensis,* the same as he would collect on the grape in Colorado. So far as we know, none of the other eight varieties of the species have been recorded from this State.

The Common Name of the Insect.—The insect treated of in this bulletin is probably best known by the vineyardists of the State as the "thrips" or "vine thrips." This name, however, is improperly applied to this insect, since the term "thrips" rightly belongs to insects of a different group. The true thrips, if they have any wings at all, have delicate fringe wings, and are not so active as the leaf-hopper. The thrips are very small, slender bodied insects, ranging from yellowish to black in color, and will be most easily found in flower cups, where they feed upon the sap of the different parts of the flower as well as upon the leaves. There are several injurious species of thrips, but none do much damage, so far as observed, to the grape. One particular species has become a very important pest to fruit trees in the Santa Clara Valley. To avoid confusion, therefore, the term "thrips" should be applied to such an insect as this in the Santa Clara Valley and elsewhere.

The common name of the insect discussed in this bulletin, as adopted by the Association of Economic Entomologists is the "grape leaf-hopper." This is generally shortened in this State to simply "hopper" or "vine hopper," and this may be specific enough here, since, when we speak of "vine" alone there is no mistaking the kind of vine referred to; and it is generally understood that all hoppers feed on the leaf. However, the correct common name of the insect, as officially adopted, is the *Grape leaf-hopper.*

Preference for Different Varieties of Vines.—In many vineyards infested with vine hoppers it will be noticed that certain varieties of vines will be much worse attacked than certain other varieties. It may be easy, in the case of a single vineyard, to express in definite terms the preference shown by the hoppers for particular varieties; but in another vineyard in the same neighborhood these conditions may be almost reversed, so that one is hardly warranted in making a general statement that will apply to all conditions and all situations.

However, certain facts were observed which may indicate a choice

on the part of the hoppers for particular varieties of grapes. In the Lodi section the two chief varieties of grapes grown are the Tokay and the Zinfandel. Throughout all this section, so far as we observed, a distinct preference was shown for the Tokay over the Zinfandel. The Mission vines are also readily attacked by the hoppers in this section. In a particular vineyard, which contained these three varieties, the Mission and Tokay were worst infested,—the Mission a little worse than the Tokay, while the Zinfandel was distinctly the least infested. In a vineyard at Madera, which was under observation for some time, the vines which were most resistant or were less readily attacked by the hoppers were the Fehr-Yagos, Zinfandel, Alicante Bouchet, Petit Bouchet, and Mataro. Of these the Fehr-Yagos and Zinfandel showed the least injury. In this question of preference for varieties, of course the difference in the degree of susceptibility of the varieties to an equal attack of hoppers must be taken into consideration; *i. e.*, some varieties may be more weakened than others, although the hoppers may be present in equal numbers. The actual difference in the numbers of hoppers, however, may be very readily determined by jarring the vines and observing the numbers flying about them. The difference in numbers in most cases is so great that there is little difficulty in judging this. The larger numbers of hoppers will always be found on the vines showing the most injury unless, of course, it is on those vines that are so badly injured that most of the food supply is gone and they are obliged to go elsewhere for food.

DEVELOPMENT.

Length of Life Cycles.—Hoppers hatching from eggs in midsummer or early fall remain over winter and attack the vine as soon as the foliage appears in the spring. Here they feed for a month, after which egg laying begins, and which may continue for two months longer. This will take it to midsummer again, so that the length of this life cycle is approximately one year. Large numbers of overwintering hoppers were enclosed in cheese-cloth bags in the vineyard, and the hoppers were observed to begin dying off in June, and by the last of July practically all were dead. Hoppers hatching from eggs laid in May and June begin laying eggs upon reaching maturity five weeks later. Egg laying continues for a month or two longer, when they in turn begin to die off, thus making the length of this life cycle from three to four months.

Number of Generations.—The number of generations of the insect as indicated above is two. Although these broods may overlap one another they are very distinct, and, at least in the Lodi section in 1907

and 1908, there was no indication of a third brood. There were two well marked periods of breeding, and none were seen pairing excepting during these periods. For the overwintering hoppers this period was during the last week in April and the first two weeks in May. For the summer brood, or those hatching from eggs laid in May and following, the breeding period extended over the last week in June and the greater part of July, the maximum pairing occurring about July 10th. The breeding period of this brood is thus seen to be greater than that of the winter brood because of the prolonged hatching period of the preceding generation, while in the case of the overwintering hoppers they all reach maturity at about the same time and pairing takes place within two or three weeks.

The best evidence of the number of broods is indicated in the well defined periods of breeding, but this fact is further strengthened by the appearance of the nymphs. A couple of weeks after the maximum breeding young nymphs appeared in great abundance, while the appearance of the young gradually diminished as the time from these dates increased. By September 1st very few young nymphs were seen, and all stages of nymphs were gradually disappearing and none at all were seen after October 15th. If there was even a partial third brood it would be expected that young nymphs would be found up to the time the leaves fell from the vine; but this would not necessarily indicate a third brood, for it might be due to the prolonged development of the second brood. The absence of any pairing of individuals of the second brood during the late summer or fall, and the young nymphs ceasing to appear at the normal time after the breeding period of the preceding brood, indicate quite clearly that there are two generations of the insect in a year.

Comparison of Development in Other Localities.—At Fresno, one hundred and thirty miles south of Lodi, where the temperature is considerably higher than at the latter place, the hoppers go through apparently the same development, although the different stages in the life cycles appear from a week to two weeks earlier than at Lodi. Continuous observation was not made on the hoppers in the vicinity of Fresno, but several trips were made to this section during the season and the life history checked with that of Lodi, except that it was a week or two earlier. In a visit to this territory on October 20th no nymphs were found in any stage, and this would seem to indicate that there are but two broods as at Lodi.

NATURAL CONTROL.

Climatic.—The sudden decrease in numbers of insects without any known specific cause, a condition frequently observed, is often attributed to the general and more or less indiscriminate term "weather conditions." Grape leaf-hoppers, are known to occur in excessive numbers more or less periodically, and, for lack of definite information, we ascribe the cause to climatic conditions. Whether these conditions have a direct effect in reducing the numbers through exposure, or through sudden increase or decrease of temperature, or through humidity, or the indirect effect of these influences in inducing disease, in favoring the development of parasitic and predatory enemies, in reducing fecundity, or in unfavorably affecting the food supply, are points not easily determined.

Fig. 15. The larva of a lace-wing fly. The commonest predatory enemy of the hopper in California.

We have, however, apparently some evidence on the direct effect of unfavorable weather conditions in reducing the number of grape leaf-hoppers. During March, 1907, there were two or three weeks of almost continuous rain. At the end of this period the hoppers were found dead in large numbers in all the vineyards in the Lodi section. Between seven and eight hundred dead hoppers have been counted under a single bunch of alfilaria. In certain vineyards that were flooded with two or three feet of water the hoppers were nearly all destroyed. This latter, of course, is an unusual condition, but unfavorable weather conditions of winter or early spring no doubt destroy large numbers of these insects.

Parasitic.—The grape leaf-hopper appears to be particularly free from natural enemies, and this is especially true of parasitic enemies. In many hundreds of eggs, nymphs and adults examined and kept in breeding cages during the season we did not find a single specimen parasitized.

Predatory.—Most of the natural enemies of the hopper come under this category of predatory or predaceous enemies, but even this list is not large. The most common of these observed during the season was one of the aphis lions or larvæ of a lace-wing fly (Fig. 15). These were present in most of the vineyards, and were frequently seen feeding on the nymphs of the hoppers, but their number was not large enough to have any appreciable effect whatever in reducing the abundance of the grape leaf-hoppers. Ladybird beetles and their larvæ were also seen to feed upon the nymphs, but they did not occur in

large numbers. Certain spiders which make their webs at the crown of the vine seem to depend for food very largely on the adult hoppers that are caught in their webs. Ants were occasionally seen carrying away young nymphs in their jaws. The ants were not long in discovering our supply of nymphs in the laboratory, which was on the second story of a building, and soon established a regular line of march, where they could be seen carrying away nymphs to their nest in the ground below. A small red mite was occasionally found on the hoppers at Madera, but we do not know that the hoppers were actually killed by this parasite.

Fungous.—It is said that a fungus belonging to the genus Epusa destroyed the hoppers in Connecticut in 1890.[1] We saw no evidence of fungous disease during the past two years. Neither was there any great mortality of hoppers observed, except in the egg stage mentioned in another place, and in this case it seemed to be due to the infertility of the eggs rather than an attack of fungous disease. Since, however, these insects occur in large numbers and are closely associated, once a fungous disease gets a foothold, large numbers are likely to be destroyed.

MECHANICAL CONTROL.

Blowers and Suction.—On account of the habit of the hoppers of flying about in the vicinity of the vine when disturbed, it was thought that there might be a possibility of drawing them into a machine by means of suction. A suction machine was designed and is said to have worked successfully in capturing the Rocky Mountain locust in 1874 and 1876 when the notable outbreaks of these insects occurred. This principle of suction is also used in sawmills for carrying away the sawdust.

We started out on this problem by experimenting with a ventilating fan run by a gasoline engine. It was possible to draw in good sized pieces of paper and other objects heavier than small insects, but the distance through which the suction worked with sufficient force was too short to be of any practical use against the hoppers. In order that such a machine may work successfully it would be necessary to draw in the insects for a distance of at least three or four feet. This might be accomplished with a very much larger fan, but this would involve the use of heavy machinery that would be unwieldy for use in a vineyard, so that we abandoned the idea of control by suction as impracticable.

With suction the air is drawn in with about equal force in all directions from the end of the tube, so that there is not much force at

[1] Thaxter, R., Conn. Sta. Rept., 1890.

any particular point; but the air is blown out of the machine in a very definite column and with much force. With our experimental fan, objects that could be drawn in only when within a range of a few inches, could be blown out many feet. This induced us to try blowing the hoppers into a funnel-shaped receptacle. For this purpose a large blacksmith's rotary bellows was used, with a large galvanized iron funnel three or four feet in diameter for the receptacle. The blacksmith's bellows did not produce an air current of sufficient diameter; for this to work successfully the diameter of the current of air should be at least three or four feet, and this again would require bulky machinery. The hoppers also held on very tenaciously to the opposite side of the leaves when the air current was turned on them, and thus it was impossible to get them all off the vine. While this method of fighting the hoppers gave more promise of working successfully than the suction method, it would necessitate the use of rather expensive and cumbersome machinery that would not appeal to the practical vineyardist.

Torches.—On account of the difficulty of killing adult hoppers with any spray while they are in the air, we tried the torch as a means of overcoming this difficulty. The torch, which was tried, consisted of burning the kerosene as it left an ordinary spray nozzle which would throw a very fine mist spray. This was tried during the dormant season on the hoppers as they would fly up from the vegetation growing in the vineyards. Even with this many hoppers would escape around the edges of the flame, and this, together with danger of scorching the vine when in foliage, led us to put this method in the negative list of remedies.

Dry Powders.—It has been very positively maintained by certain growers that they could kill the nymphs of the vine hopper very successfully by the use of air-slaked lime. In order to determine this we made a number of experiments by keeping nymphs in all stages in a vial and thoroughly dusting them and filling the air in the vial with lime, but many did not appear to be inconvenienced by this treatment. This method was carried out on a practical scale by thoroughly dusting a row of vines through a vineyard by means of the French vermorel machine used in applying sulfur for the *Oidium* (Fig. 16). The air-slaked lime had no effect whatever, so far as could be observed, on the number of nymphs.

Pyrethrum was used with better success in the laboratory experiments where the hoppers were confined, but the results in the vineyard were not at all satisfactory in controlling the nymphs. The expense, moreover, of pyrethrum if used on such a large scale would be too great to make this a practical remedy.

The idea that prevails with some, that sulfur is of use in killing the hoppers, is not borne out by facts. Hoppers, in all stages, confined in our breeding cages in the vineyard, thrived well in spite of the fact that large amounts of sulfur were blown into and held in the cages during the frequent sulfurings for *Oidium*.

Sticky Shields.—Sticky shields have been used to some extent in fighting the grape leaf-hopper, but a large number escape by this

Fig. 16. Applying air-slaked lime for the nymphs of the hopper by means of the French vermorel machine.

method so that their use is not thoroughly satisfactory. A sticky shield held on the leeward side of the vine and the hoppers jarred off will catch many, but a large number will not strike the shield. A three-sided box for our California vines works best, but even here many will drop to the ground or fly out on the open sides. In the New York vineyards, two men each carrying light sticky shields three or four feet high and seven or eight feet long on opposite sides of trellised vines, has been found to be a fairly successful method of capturing the hoppers. Probably the best sticky material for use on the shields in this State is the ordinary crude oil.

Fumigation.—A good many experiments were carried on with a view of determining the feasibility of fumigation as a means of controlling the vine hopper. The vines were enclosed either in canvas tents, or a galvanized iron tank or drum inverted over the vine, or a square box made of building paper (Fig. 17). In most of the experiments carried on the tank or box was used, since the air capacity did not vary in these as was the case with the loose canvas tents, and the dosage could be accurately calculated.

One gram of cyanide of potassium to thirty cubic feet of space was

Fig. 17. Fumigating box made of building paper, used in the experiments on fumigation.

found to kill the hoppers in from five to ten minutes. In some cases with this dose, however, a few of the most tender leaves would be slightly burned. The work was done, however, during the day time, when the vine is more active and more susceptible to the gas than at night. Because of the short exposure necessary to kill the hoppers a few tents would be sufficient to keep a crew of fumigators busy, so that the initial expense of apparatus need not be very great. The dose necessary for each vine is also small, so that there is not a large expense of chemicals. The moving of the tents from vine to vine and the weighing and charging of the chemicals, however, require much time

and labor. The accurate weighing of such small quantities of cyanide and the liability of injuring the vine or not killing the insects, if this is not carefully done, make the method too complicated for the practical vineyardists, besides being more expensive than other methods of control discussed farther on.

Some experiments were tried by a vineyardist near Lodi with burning sulfur and liberating the gas in a drum enclosing the vine, as shown in figure 18. A fire was made in a small cylinder on the side of the drum and sulfur blown over this by means of an ordinary sulfur bellows,

Fig. 18. An apparatus for fumigating with the fumes of sulfur, designed by a vineyardist at Lodi. The tent in the background is for hydrocyanic acid gas.

thus converting the sulfur into a gas which was conducted through a tube entering the drum near the bottom. It was difficult to regulate the amount of gas with this apparatus, so that the vines generally were badly scorched. Some modification of this apparatus might be made to work successfully; but sulfur fumes SO_2, at least when used alone, is not, apparently, a good insecticide, and on the other hand, plants are very susceptible to injury by this gas. There is, therefore, a very small margin, if any, between a dose that will kill the insects and not injure the plant. A grower at Madera thought he could kill the hoppers by burning sulfur between the vines. A handful or two of

sulfur on a piece of burlap sacking was placed between every four vines over about one quarter of an acre, and the sulfur burned. The hoppers apparently suffered no discomfiture, but the foliage on the windward side of the vines was badly burned.

Sprays and Washes.—Various kinds of sprays and washes were tried for killing the adult hoppers in the spring, and also during the winter while they were still on their winter food-plants. None of these were successful because of the activity of the hoppers, for it was impossible to drench those in the air thoroughly enough to kill them.

Fig. 19. Spraying for the nymphs.

Pure kerosene was used while they were still on the vegetation in winter, and even with this strong material probably the larger per cent escaped on account of their activity. They could, however, be quite readily killed if they were against something, as the ground or a leaf, where the spray would wet them thoroughly.

Spraying for the nymphs, however, is a different problem, and it is practical to get a very large per cent of them by this method. The nymphs are all on the underside of the leaves and they are not capable of flying or jumping, so that it is possible to hit them with a spray. The sprays which gave the best results were the whale oil soap solution and the resin spray,—the soap solution being probably a little the better.

One pound of soap was used to fifteen gallons of water. In the case of the resin one pound was used with fifteen gallons of water and enough lye or potash to completely dissolve the resin. This is at the rate of one pound of lye to about eight pounds of resin.

The time to spray for the nymphs is when they first reach their maximum numbers in the spring, just before the first of them change into the adult winged hoppers. This was during the last of May and the first of June during the past two years at Lodi.

The spray should be applied from below and the under side of every leaf thoroughly wetted with the solution, since the spray will kill no more nymphs than it hits. This is not very difficult to do in

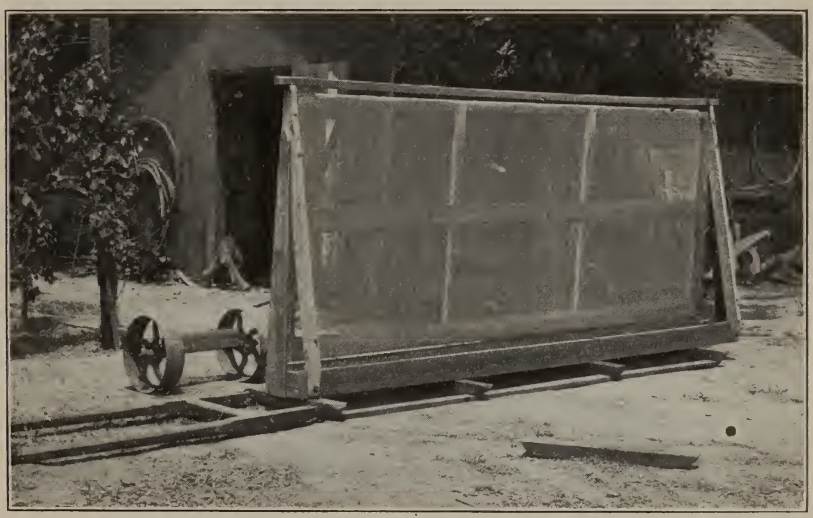

Fig. 20. An apparatus designed by a vineyardist at Madera for use against both the leaf-hopper and grasshoppers. The trough at the bottom contains crude oil, into which the hoppers are supposed to fall upon hitting the upright screen.

May or early June, while the shoots are still comparatively short. The best type of nozzle to use is the cyclone, with the spray emerging at right angles with the long axis of the rod, shown in figure 19. This will allow the operator to poke the rod anywhere among the vines without its being caught.

The spray is intended to kill the nymphs only. There are adults always present which will escape, and the spray will not prevent whatever eggs may be present from hatching later. In bad cases of vine hopper injury, however, it will pay well to do this spraying for the nymphs, if the screen method, described below, has not been used or the work not effectually done.

Screens or Cages.—In our work of spraying for the adults it was soon determined that, if a spray was to be used successfully, the active hoppers must be confined within certain limits in order to give time to hit them thoroughly with the spray. The screen cage shown in Fig. 21 was developed as a result of this, it being intended to apply the spray from the open side through a hole in a canvas curtain which could be dropped down as the cage was pushed onto the vine. This

Fig. 21. A screen cage used to capture the grape leaf-hopper.

was found to work quite satisfactorily. It was noticed, however, that when the base of the V-shaped opening on the bottom of the cage struck the vine most of the hoppers were jarred off. This suggested the use of a sticky material on the sides and bottom of the cage and jarring them on to this, and thus dispensing with the spray.

This method of capturing the adult hoppers by means of the screen cage in the early spring proved to be the most successful of all the means of control tried during the season.

The screen cage is made by tacking a double layer of ordinary

galvanized mosquito wire-netting over a square frame of wood or laths or other light material. A single covering of mosquito netting will allow some hoppers to escape through the mesh. If it is obtainable, a 20-mesh screen would be preferable. Ordinary galvanized mosquito wire-netting, however, can be obtained almost anywhere, and two layers of it work very satisfactorily. The bottom of the cage consists of a shallow tray. This is made by turning up about an inch or an inch and a half of the edges of a sheet of light galvanized iron. There are two grades of this iron, and the heavier grade adds much more weight than is necessary. One side of the box is kept open and there is a V-shaped opening (Fig. 22) in the tray at the bottom which permits the cage to be pushed on to the vine. At the same time that the cage is swung into position the vine is bumped by the base of the opening, which is padded with leather, thus jarring the hoppers off. The sides and bottom of the cage, having been previously smeared with crude oil, catch all the hoppers that fall on to them. The cage should be operated with the open side facing the direction from which the wind is blowing. If there is a breeze blowing, very few will escape on the open side. However, if there is no breeze, and the hoppers are especially active, a canvas curtain fastened on the front of the cage at the top can be very readily dropped down as the cage comes into position, thus shutting off all possibility of escape.

Fig. 22. The hopper cage with the V-shaped opening at the bottom covered with canvas.

The bottom of the cage is a very essential feature, since most of the hoppers drop to the bottom at the back of the cage or are caught within a foot or two from the bottom on the sides. To prevent any escaping by dropping down through the opening in front of the vine this may

be covered with canvas as shown in figure 22. Two pieces of canvas meeting in the center are tacked on the sides of the opening. Pieces of rubber tubing extending transversely are sewed on the canvas and their ends securely tacked down at the sides, leaving them otherwise free, excepting as they are fastened in the canvas. As the cage is pushed on to the vine the canvas and the free ends of the rubber give

Fig. 23. A photograph of the interior of the cage shown in Fig. 21, after 15 minutes use where hoppers were very abundant. The white specks at the back each represents a hopper, stuck in the oil with which the screen has been smeared. A portion of the tray at the bottom, which is outside the shadow on the left, shows a solid surface of hoppers.

way, but immediately spring back into position again on account of the flexibility of the rubber tubing. This canvas may be covered with oil, and thus the bottom is completely covered.

The advantage of the screen is that it does not shut off the light and also allows the wind to blow through so that the great majority of the hoppers will go downward and toward the leeward side of the vine. A cage built of canvas was tried, but proved unsuccessful because

most of the hoppers came out on the open side toward the light, and it was with difficulty that they could be caught on the black oiled canvas. The canvas also absorbs more of the oil than the screen and makes a drier surface for the hoppers to light upon, thus failing to hold them as well as the free oil on the wire of the screen.

Kerosene may be used on the screen as well as crude oil, but it evaporates more rapidly and more frequent applications are necessary. For a fine mesh screen, however, the kerosene works very well, since it does not darken the sides so much as the black crude oil.

The time to use this screen cage is in the early spring when the shoots of the vine are not more than four or five inches long. At this time all the hoppers have left their winter food plants and have begun to feed upon the vines, and none have yet laid eggs. This method, therefore, captures them at a critical time before they have begun to breed, and thus greatly reduces the numbers of the succeeding generations.

The work may also be done more easily and effectively at this time, since there is not the excessive foliage that appears as the season advances. The size of the vines to be treated will determine the size of the cage. Ordinarily, the cage need be but very little larger than the diameter of the vines after pruning. In one young vineyard, two years old, the hoppers were kept down successfully by a small cage about one foot square, which was easily handled by one man. With the larger cages three feet square, handles are attached to each side and the cage manipulated by two men. One of these cages with two men will go over four or five acres a day. There is practically no expense for materials and the time of the men is the chief outlay.

If this screen cage is conscientiously used it will capture from 85% to 95% of the hoppers, and at a time in the life-history of the insect when for each hopper taken it means a hundred or so less later in the summer.

This method of capturing the hoppers with the screen cage was developed for vines that are headed some little distance above the surface of the ground. There are many vineyards in the State, however, that have not been so pruned. Some are headed directly at the surface, and in some even the canes come out from the stump beneath the surface, and a cone-shaped area is scooped away to make room for the growth of the canes. This form, in some cases, is given to the vine by frost; but where the pruning is responsible, it is generally considered now to be a bad system.

If the cage is to be used on such vines, it must be done with some modification of the bottom or the bottom dispensed with entirely, though this is an important part of the apparatus.

In the case of staked vines it is possible to work this cage if the top is left off, or enough of the top so as not to interfere with the stake. An opening may be left in the top similar to the V-shaped opening at the bottom. A staked vineyard was gone over with this modified cage and practically no hoppers escaped through the opening at the top. Such an apparatus can not be used at all, of course, on trellised vines. For trellised vines we would suggest the use of sticky shields as are used in New York vineyards, excepting that the canvas be replaced by wire screen netting. These should be three or four feet high and seven or eight feet long, and two of them operated together on opposite sides of the trellis.

FARM PRACTICES.

Plowing.—Plowing is sometimes done by California vineyardists during the winter season for the purpose of destroying the grape leaf-hoppers. This is partly based upon the supposition that the eggs may be in the leaves or in the ground, or that the adult hoppers are in some way killed in the operation. So far as having a direct effect in destroying the hoppers is concerned, plowing is of little avail. The only ones that will be killed are a few that may not be disturbed from their resting places among the leaves, or otherwise accidentally buried by the plow. During the cold or rainy days there may be a few thus turned under, but ordinarily they are active enough to escape readily before the plow.

Plowing, however, may have an indirect effect on the hoppers by depriving them of food, or of suitable sheltering places during unfavorable weather conditions, and if this practice is generally carried out in a neighborhood it will no doubt result in reducing the numbers somewhat. However, a field may be free from hoppers during the winter, but this is not necessarily an indication of freedom from spring infestation. The insects are more generally distributed in the winter season, but the bulk of them will usually be found in the vineyard, or on the vegetation of the borders immediately surrounding it. They may come in, therefore, from vineyards closely adjoining, so that plowing a single vineyard may be of little help. When the plowing is done in a single vineyard or over a small area it is likely to result simply in driving them into other fields, where there is a better food supply. Once in these other situations they may, or may not, come back into the vineyard where they were originally.

Sheeping.—Some growers turn sheep into the vineyard soon after the crop is harvested and allow them to eat off the leaves of the vines. This should not be done until the leaves have completed their growth

and are about ready to fall naturally. The chief result of this practice is to drive the hoppers elsewhere for food. In the late fall the adult hoppers are still feeding on the vine foliage, and there they continue to feed until the leaves lose their succulent material and dry up. When sheep are turned in among the vines and the foliage eaten off, the hoppers will either go to an adjoining vineyard that is still in foliage, or simply begin to feed a little earlier on their wide range of winter food plants which may be growing in the vineyard or vicinity. The destruction of the leaves, however, does away with the sheltering places that would be formed by the leaves accumulating in bunches by the wind; and a clean vineyard is always freer from hoppers in the winter season than one where there is an abundance of leaves or of growing vegetation. But there is nothing to protect such a vineyard from a possible infestation in the spring from the adjoining vineyards.

Plowing and sheeping, then, result chiefly in partially destroying the food supply over a limited area, and of doing away with possible hibernating places in the bunches of leaves that would otherwise accumulate. The usefulness of such practices will depend largely on how generally they are carried out in a neighborhood, and at best can be counted on simply to reduce the number of hoppers, which, generally, is not likely to be at a point of effective control.

SUMMARY.

The grape leaf-hopper is one of the most important insect pests of the vine in California, as may be seen by the most casual observer in the large amount of foliage that dries up prematurely on the vines in many sections of the State each year.

Life History.—The hoppers pass the winter as adult insects on a wide range of food plants that may be growing in the vineyard or vicinity. They attack the vine as soon as the foliage appears, and here they remain until the leaves fall in the autumn.

One month after they begin feeding on the vine, the overwintering hoppers begin egg laying, which is continued over a period of a month or two, after which they die. The hoppers of the spring brood arising from eggs laid in May, become full grown in three weeks, begin egg laying two or three weeks later, and die off in August or September, making the life of this spring brood approximately three or four months. Hoppers arising from eggs laid by the spring brood in June and later, remain on the vine until the leaves fall in autumn. They then take to whatever succulent vegetation may be present in the neighborhood, where they live over winter and attack the vines again in the following

spring. These begin depositing eggs a month after the leaves appear on the vine, and die off in midsummer, making the length of this life cycle approximately one year in the central valleys of California.

Control.—The most satisfactory control method tried during the past two years was the use of the screen cage. This was found to capture about 85% to 95% of the adult hoppers at a time in the spring before any eggs are deposited.

Spraying for the nymphs about June 1st, or just before the spring brood becomes mature, will kill a satisfactory percentage of the nymphs or young, but will not kill many adults, or prevent eggs, which are present at this time, from hatching later. If the cage method has not been used, or satisfactorily operated, spraying for the nymphs will very materially aid in reducing the numbers of the spring generation.

Plowing or other farm practices can not be relied upon, but when such measures are generally practiced throughout a neighborhood, they may aid in reducing the numbers somewhat.

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32. White Fly Eradication.
33. Packing Prunes in Cans. Cane Sugar vs. Beet Sugar.
34. California State Farmers' Institute at the University Farm.
35. Southern California Pathological Laboratory and Citrus Experiment Station.
36. Analyses of Fertilizers for Consumers.

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